Circling the Wagons: Agriculturalists and Conservation Biologists Must Cooperate to Protect Endemic Hawaiian Invertebrate Diversity and Control Invasive Species

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Abstract. Conservation of native Hawaiian insects and suppression of invasive species are intrinsically connected propositions. The isolation of the Hawaiian Islands has produced a large endemic insect fauna that is ill equipped to compete with the onslaught of species that have been intentionally or inadvertently unleashed. However, most of the data needed to effectively preserve natives and control invasive species is lacking. Research on the impacts of invasive species, the mechanisms of the impacts, and control methods has just begun. Funding efforts have likely been hampered by legislation which ignores, or gives very low priority to insect conservation. Better cooperation and support between insect conservationists, biological control specialists, botanists, and other branches of research are needed. Additionally, Hawaiian entomologists must inspire the public at a grassroots level in order to increase support for insect conservation. Biologists concerned with preserving Hawaiian ecosystems and agriculture must recognize the extensive common ground we share, and identify ways to support each other towards the accomplishment of common goals.

Introduction

Due to their isolated location, it is estimated that before human contact a new species established in Hawaii on average once every 70,000–90,000 years (Ziegler 2002, p. 166). Since the first humans arrived, the number of invasive species arriving in Hawaii has increased dramatically. While intact, diverse ecosystems tend to be relatively resistant to new invaders (Van Ruijven et al. 2003, Kennedy et al. 2002), invasive species have penetrated all Hawaiian ecosystems (Henneman and Memmott 2001), making it impossible to know what an intact, or more resistant, Hawaiian assemblage might have been. Invasive species are establishing in Hawaii in increasing numbers, largely due to increasing trade and tourism (Reimer and Oishi, this issue). These invaders have likely been the most important cause of native species decline and extinction (Loope and Krushelnycky, this issue), making insect conservation biologists and invasive species biologists natural partners in mutually beneficial efforts. However, despite such common ground, very little research has been done on the impacts or pathways by which invasive species impact native species. Once the most detrimental invasive species have been identified, control methods (again a shared goal of invasive species and conservation biologists) can follow. While this isolation has probably made native Hawaiian species more vulnerable to invasive competitors, it also potentially provides a buffer against even greater rates of introduction if quarantine efforts are properly supported. Based on reports in this issue, it seems likely that a properly supported and staffed department of agriculture could significantly reduce the rate of new introductions. This might not be possible in a mainland system where physical connections and personal vehicle traffic make thorough inspections impractical at nearly any imaginable level of staffing. In this paper I suggest a scale and strategy for insect conservation efforts, present some of the ways invasive species are impacting native taxa, outline directions for future research, and discuss under-exploited opportunities to improve the funding situation and raise the profile of invasive species control and native conservation.

Scale of insect conservation. Because most conservation planning is based on vertebrates or plants, conservation management is likely to miss the 'middle ground' that many invertebrates may represent. Many insect herbivores are able to persist on very small patches of their hostplant for long periods of time (Rubinoff and Powell 2004). However, most vertebrate planning abandons areas smaller than a mountainside, and plant conservation can often focus on a scattering of individuals maintained in gardens and reserves. Most insect herbivores do not occur across the full range of their hostplants—even on a local scale (Fleishman et al. 2000)—making it important to save patches of hostplants across ecotones. Such patches may be effective in maintaining viable insect populations or metapopulations, even if only a few individual plants are present (Rubinoff and Powell 2004, Guittierez 2005). Additionally, research suggests that many insect populations may operate as metapopulations vulnerable to inbreeding and (Saccheri et al. 1998), enduring regular local extinction and recolonization events under stochastic patterns (Hanski and Gilpin 1997, Hanski and Gaggiotti 2004). Under such a pattern fully 50% of the needed habitat for an insect species might be unoccupied on a given year, but if such vacant habitat is eliminated, the chance for long-term persistence declines dramatically (Guttierez, 2005). Research to discover the sizes and distributions of these "mini-reserves" for various insects of conservation concern might lead to effective collaboration between botanists and entomologists to preserve threatened plant-insect relationships, not just individual species.

Predators and parasitoids. Introduced predators, especially ants (Loope and Krushelnycky, this issue), vespid wasps, and introduced parasitoids (Henneman and Memmott 2001) appear to have had severe negative impacts on populations of native insects (Howarth 1991, but see Follet et al. 2000). However, efforts to assess the severity of the impacts of these introduced predators, and to identify the most damaging species in Hawaii are limited (Gillespie and Reimer 1993, Krushelnycky et al. 2005). Such research is an essential first step towards focusing control programs on the worst invaders. To this end, Hawaii has an unusual advantage. Because many of the most damaging invasive species belong to groups with no native members (ants, vespid wasps), control programs could have broader impacts than would be permitted for mainland exterminations. Specifically, because Hawaii is without native social insects, we are free to engage in sweeping control strategies, affecting a wide range of ants or social wasps, that would be untenable in continental areas due to non-target effects. This opportunity presents challenges since Hawaiian researchers will need to generate unique control strategies without out-of-state assistance since other researchers could not consider such draconian methods.

Habitat loss. The destruction caused by invasive plants to native insects may be underestimated. As native plants are displaced, native herbivorous insects and their native predators also suffer. Native insects may be more vulnerable than their native hostplants since insects frequently exist in a subset of their hostplant's range. Little research has been done in Hawaii to identify optimal elevations for the richest native insect communities as related to the past and current distribution of particular hostplant species. For example, *Metrosideros* occurs from sea level to 2400 meters, but the richest assortment of dependent insects may occur perhaps between 1000 and 2000 m elevation. Identifying elevation based hotspots of insect diversity might help prioritize habitats for preservation and restoration. Otherwise native plants may persist in fractions of their original range that are unsuitable to a large compliment of their native herbivores. Such research could be conducted in cooperation with native plant specialists to develop a more inclusive conservation plan for different Hawaiian ecosystems.

Competition. Invasive organisms can have subtle, but important, negative impacts through competition for resources with native species (Simberloff et al. 1997, Suarez et al. 1998). For example, introduced taxa as apparently benign as feral honeybees may out compete native *Hylaeus* bees for limited nectar resources. Invasive parasitoids occur in even the most intact Hawaiian ecosystems (Henneman and Memmott 2001). Anecdotal evidence suggests that if native parasitoids were more flexible in their host selection, introduced parasitoids might not have been needed to protect Hawaiian agriculture since native parasitoids would have taken advantage of new food sources. The absence of native parasitoids in agricultural systems suggests that native parasitoids are host-specific, or at least unable to exploit most introduced pests. Because those introduced parasitoids are able to use a wide array of native and introduced prey, they can theoretically build up larger populations and thus have the potential to outcompete native parasitoids for larval resources, though the mechanism is generally unconfirmed, parasitoid competition has been noted in other parasitoid systems (Simberloff 1996, Simberloff and Stiling 1996)). Additionally, if introduced parasitoids attack smaller, younger larvae, they may have a distinct competitive advantage over native species that require larger late instar larvae (M. Heddle, personal communication). These concepts are largely based on observation and anecdotal evidence; experimental data detailing competitive interactions and impacts must be collected.

Future prospects. Virtually nothing is known about effectiveness of habitat restoration for native insects. Because insects operate on a finer spatial scale than many vertebrates (Rubinoff 2001), there may be unique opportunities to save them. Planting of native trees instead of introduced or invasive species that are currently used by government agencies along roadsides and for soil retention in watersheds and in state forests would significantly increase the habitat available to native insects. Such action might also help to raise public awareness of the value and plight of Hawaii's native insect fauna by making native species more visible. Grassroots efforts to educate the public about the importance of native insect and plant communities might go a long way towards protecting insects. Not only might many species be able to use suburban native plant gardens to sustain populations, but these efforts also would raise the profile of native insects on the legislative forum and thereby encourage more funding for the research needs mentioned previously. Public support will likely be crucial to providing legal protection and funding for research on native insects.

Current funding and legislative support for Hawaii's invertebrate fauna is far below levels for virtually all other groups of organisms. This is true despite insects being the group with the highest number of endemic Hawaiian species (Ziegler 2002, p. 157). Nationally, the 2006 Endangered Species list has 988 U.S. species listed as "endangered." Of these only 47 are insects and arachnids, giving insects a national ratio of 1:21 when compared to other protected animal and plant species. Because Hawaii lacks much of the "sexy" megafauna of mainland areas, and because most of Hawaii's insects are found nowhere else, one might presume a brighter conservation situation in the state. The contrary is true: in 2006, Hawaii had 312 species listed as endangered, but of these only 3 were terrestrial invertebrates, meaning invertebrates endure a 1:104 ratio of legislative protection in the state. This discrepancy on the state and national levels might suggest that insects are less likely to be threatened with extinction. Unfortunately this is not the case. McKinney (1999) demonstrated that threat of extinction is distributed evenly across organisms, and therefore, that understudied, diverse groups—especially insects—are at a higher risk of extinction than mammals and birds because insects are, relatively speaking, so poorly known.

Hawaii's discrepancy is five times worse than the national average. Insects represent Hawaii's largest, most endangered, least studied and most poorly protected form of native biodiversity.

The Kauai green sphinx (*Tinestoma smargaditis*) is a case study of the failure of the *status quo* to save poorly known rare species like threatened invertebrates. In over 100 years only about 20 of the moths have ever been seen, and only from a few parts of Kauai. The moth was a candidate for listing under the Endangered Species Act but was recently dropped from consideration. The reason given was that there was no data available on what constitutes "critical habitat" for the moth. This designation of habitat is a prerequisite for listing, but requires research which will not be funded, especially now since the moth is not even listed! Therefore the moth remains extremely rare, likely critically threatened, and essentially unknown. A "Catch-22" for extinction.

It is certain that insects represent a large and essential part of Hawaii's native natural history. It is also clear that the *status quo* is not providing for adequate research on, or control of, invasive species that are destroying the native insect biota. A "circling of the wagons" facilitating and encouraging cooperation among a diverse group of professionals ranging from quarantine inspectors to invasive species biologists (including biological control) to insect and plant conservation researchers to share data and coordinate priorities and actions would be an important first step towards improving the plight of native insects. While this diverse collection of people and missions is unlikely agree on the best methods or targets for research, preservation, or control, our motives and ultimate goals of suppressing invasive species and promoting native biodiversity are shared. Without unity and a change in organizational strategy (Figure 1), the status of Hawaii's unique invertebrate fauna will continue to deteriorate and irreplaceable components of the Islands' ecosystem will be lost forever.

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Figure 1. Circling the wagons.